

EDUCATION IN APPLIED
SCIENCES IN INDIA

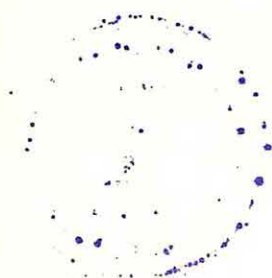
A. R. VERMA



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IN INDIA**

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Education in Applied Sciences in India

In this lecture I shall deal with the growth and development of modern sciences starting from the times of the British regime in India in the beginning of the nineteenth century.

It was through the British that India received some education in modern science. We may recall that the Calcutta Madarsah was founded by the first Governor General, Warren Hastings, and was followed by the Banaras Sanskrit College. The colonial rulers were interested in exploring the resources of India and in exploiting them and also wanted to provide an infrastructure for governing the country. Therefore their scientific policy was designed to suit these purposes. In this connection it is interesting to note that in 1813 when the Charter of the East India Company was renewed, a clause was introduced which reads : "a sum of not less than one lakh of rupees might be spent for the introduction and promotion of knowledge of sciences among the inhabitants of the British territories of India". In 1817 the Calcutta Mahavidyalaya was set up by David Hare and Raja Ram Mohan Roy for the instruction of the sons of the Hindus in the European and Asiatic languages and sciences.

As I said, the British rulers were interested in acquiring knowledge about the various resources of India. Therefore, they set up the organisation called the Survey of India. This led to the development of other Surveys such as the Geological Survey, the Botanical and the Zoological Surveys and the Archaeological Survey. Through these Surveys, the first map of "Hindoostan" was prepared by Rennel, the Surveyor General of India in 1783. A trigonometrical survey of the Himalayan region was conducted in 1818 by Everest.

Lecture delivered by Dr. A. R. Verma, Director, National Physical Laboratory, New Delhi, on 23 November 1981 before the National Institute of Education Faculty.

In 1857, the first three Indian Universities in the presidency towns of Calcutta, Madras and Bombay were established and then came the Universities at Lahore and Allahabad. The British rulers required a system of transport and communication and hence the telegraph and railways were developed. In 1875 the Meteorological Department was started.

Next, the Administration felt the need for local doctors and engineers. Thus the Medical Colleges in Calcutta, Bombay and Madras came into existence. Soon thereafter the Engineering Colleges of Sibpur (Calcutta), Poona and Roorkee were also started. It is significant that the Imperial College, Roorkee—a leading engineering college—imparts instruction only in civil engineering because this was the area in which the British rulers wanted Indians to work rather than those areas of engineering which are needed in the development of technology. The need for skilled craftsmen led to the establishment of the Victoria Jubilee Technical Institute in Bombay, and a school of industrial arts in Madras. Agricultural and veterinary schools were also started at several places in the presidencies.

The period 1880 to 1900 saw the emergence of several distinguished persons, such as Asutosh Mukherjee in Mathematics, J.C. Bose in Physics and P.C. Ray in Chemistry. P.C. Ray visualized the establishment of the Indian Chemical Industry. In 1876 the prestigious institution, the Indian Association for the Cultivation of Science, was started by Mahendra Lal Sarkar. It was in this institution that C. V. Raman worked and discovered the famous Raman Effect in 1928 and won the laurels of the Nobel Prize in physics in 1930. The progress went on and by the end of the nineteenth century, India had 170 colleges and four medical and four engineering colleges. In Bangalore, the present Indian Institute of Science was started by Tata in 1909. It was against this background of educational facilities in science and technology that Mahamana Malviyaji came on the scene of education in India, and founded the Banaras Hindu University in 1916.

The teaching of and research in sciences in Indian Universities was, and is, even now, largely confined to what may be called the pure and fundamental aspects of the subjects.

What do we mean by fundamental and applied sciences? Let me define the terms (i) *basic, pure and fundamental research*, (ii) *applied research*, (iii) *design and development*.

Pure, fundamental or basic research is directed towards a fuller understanding about ourselves and nature. Within this, one may also consider oriented basic research which is focussed on a given theme. The aim is to expand the frontiers of knowledge with no immediate practical application in mind. For example, consider the question which Prof. C.V. Raman asked to satisfy his inquisitive mind. Why is the sky blue? He wanted to understand this just for the love of it. A consequence of this attitude is that one is happy to share this in technical fields, the knowledge is not published but one files a patent and wants to preserve the right in exploiting that knowledge commercially. One must, however, realize that the pure and fundamental research of today appearing to have no immediate practical application, may, in future, find immense practical use, and hence, may become of great commercial value. One may illustrate this by an oft-quoted experiment by Faraday. This is a simple experiment with a closed loop of wire having a galvanometer in the circuit. When a magnet is brought towards the loop of wire, there is a transient deflection in the galvanometer showing the generation of an electric current which lasts as long as the magnet is in motion. This observation of Faraday was of historic significance in the laws of electromagnetic induction. At the time of this discovery, it was hardly imagined that it would be of any commercial value in future. We know now that the generation of electricity in power-houses today depends on this discovery and not only has it been of the highest commercial value to the world but it also constitutes the very basis of modern civilization.

Now consider *applied research*. It is that research activity which is directed towards a specific practical purpose. The purpose may be to serve social needs, or I may even say, unsocial uses, when it is misused for destructive purposes. The social needs from the Indian viewpoint could be to do research in agriculture and improve agricultural productivity, or similarly, to understand the causes of different diseases, to find their

cures and improve the health of the people. On the industrial side, it may be directed to a specific field of industrial activity. Let me take an example from the National Physical Laboratory with whose working I am presently associated. We have been working on the understanding of the behaviour and properties of photo-conducting materials like selenium. This knowledge has an immediate application in the design of electrostatic photocopying machines. This is applied research. After this research one has to do developmental work.

Developmental work is the research activity wherein by a systematic use of the results of basic and applied research it is aimed to introduce new materials, new products, or new processes or to improve the existing ones. Design and construction of prototypes and pilot plants form essential parts of this activity. These activities are called Research and Development (abbreviated as R & D) and Design and Development (abbreviated as D & D) activities.

May I again recall that in contrast to basic research, the results of applied and development activities are kept secret in the form of patents and process know-how and can be obtained only by negotiations and suitable payments ?

There is one other characteristic of applied and developmental research which contrasts with pure research. It is that these programmes have to be time-targeted and economically feasible. Again, to take the old example, one may devote a whole lifetime to understand why the sky is blue. But if the applied research on photo-conducting materials like selenium and its use in the designing of electrostatic photocopying machines is going to take a whole lifetime, or is going to be prohibitively expensive so as to remain beyond the reach of society, then naturally one is hardly interested in such a proposition.

The "total chain of innovations", as Prof. Blackett has called it, starts from the origin of an idea. The scientist takes up that idea and conducts basic research. It is then translated into applied research with a well-defined objective in mind. Then follows developmental work, design of a prototype, and pilot plant work to establish economic and technical feasibility. It is only after this has been successfully done that a

commercial unit is established which leads to production and it is this last step that generates wealth for the nation. It is important to have an idea of the inputs required for these stages. At a very rough estimate, it may be said that if the work in the laboratory for developing a process costs an amount 'A', it will cost 10 'A' to take it to the pilot plant stage, and 100 'A' to upscale it to the production level.

A notable trend observed in the utilization of the discoveries or technological innovations for commercial production is the continual reduction in the time gap between the discoveries and their utilization. It took some 50 years for the utilization of Faraday's discovery of electromagnetic induction in 1831 to be utilized for commercial use in the generation of electrical power. Let us now take a modern example. The transistor was invented at the Bell Laboratories in 1947 by John Bardeen, Walter Brattain and William Shockley. For this work they received the Nobel Prize in 1956. We can recall that transistors were made available within a few years after that and have been in the market for well over three decades now. Today we have integrated circuits popularly called ICs (the abbreviated form) including very large scale integration, utilizing the basic concepts and technology of this invention. The time lag between the discovery and its utilization in this case was only a few years. This time gap is decreasing fast. Today ideas are being literally lifted from the laboratories and being rapidly translated into production technologies. Indeed, one may say, the technological strength of a country can be found out from this time gap—the shorter the time gap, the greater the technological strength of a country.

I would like to take this opportunity to pay tribute to the foresight of Mahatma Gandhi. Let us see the state of education and research in sciences and technology in the Indian Universities at the time Mahatma Gandhi came on the scene. Science education in the Indian Universities was confined to education in pure sciences such as physics, chemistry, botany, zoology, etc., the emphasis being on the understanding of the phenomenon rather than its application. There were hardly any courses in the applied sciences and in the engineering and technological fields. Mahatma Gandhi, with his great fore-

sight, could see that if India had to progress in industries, the universities must impart instruction in the applied, technological and engineering sciences. Therefore, at Banaras, he started courses in electrical engineering, mechanical engineering, industrial chemistry, ceramics, mining, metallurgy, agricultural sciences, indigenous medicine and the Ayurvedic system, etc. in addition to the traditional courses in the faculties of arts, humanities and sciences. Such a broad spectrum of education in the technical sciences, as was started at Banaras Hindu University, did not exist at any university in India at that time. Students in the engineering courses were provided excellent practical training. In my childhood I had heard that the electrical engineering college of the Banaras Hindu University had offered to run a power-house and to supply electricity to Banaras town, but somehow this did not materialize and I was told that the contract was given to Martin and Burn. This concept of a university college offering to serve the needs of society by generating power and supplying it to them commercially can be discussed even today as a challenging model relevant to the present times. Students of the Banars Hindu University have occupied positions in different industries in all parts of the country. It is no exaggeration to say that systematic instruction and research in applied and technological fields was pioneered at the Banaras Hindu University under the inspiring leadership of Mahamanaji. This situation continued until Independence in 1947.

Let us now see what the situation was in India at the time of Independence, and how it has changed since then. There were 20 Universities in India in 1947. Today we have over 120 Universities including Institutions Deemed to be Universiteis and Institutes of National Importance. I do not wish to burden this lecture by including the statistics regarding these institutions but it is important to note how the total stock of scientific and technical personnel has increase during the last 30 years or so of independence. In 1950 the total strength of scientists including the degree and diploma holders in engineering and technology, the graduates and post-graduates in science and agriculture, the degree and licentiate holders in medicine stood at 1.88 lakhs and the corresponding figure in

1960 was 4.50 lakhs. In 1971 it rose to 11.74 lakhs, and as per the official estimates, this figure had increased to 23.28 lakhs in 1977. Today this figure may be almost 15 times what it was at the time of the country's independence. In terms of the absolute number of scientists and engineers in India, it can be favourably compared with the most highly advanced countries, and one often rejoices to hear that we are the third largest nation in the world in terms of trained and qualified scientific and engineering manpower, next only to USSR and US.

If we look at the "total chain of innovations", the initial part, viz., basic and fundamental research, is largely conducted in the Universities. At the other end of the chain we have production in the factories and the fields. The middle part of the chain, viz., applied research and developmental work, was lacking at the time of Independence. This gap of applied and developmental work existed not only in industrial and related areas, but also in nuclear energy and its peaceful uses: agricultural research for solving the food problem, medical research for health and human welfare, developmental work to cater to the needs of national defence in different areas.

Similarly, there were huge requirements for developmental work in the areas of railways, electronics, telecommunication, etc. Hence, Pandit Nehru, who had great faith in science, conceived the idea of establishing national laboratories and other institutions where applied research would be pursued with a view to solving these problems. As a first major step the Council of Scientific and Industrial Research (CSIR) similar to the one that existed in UK was set up with Dr. S. S. Bhatnagar as its head. This resulted in what is often popularly called the 'Nehru Bhatnagar Effect', and a chain of National Laboratories were established. In 1950, six national laboratories, viz., the National Physical Laboratory at New Delhi, the National Chemical Laboratory, at Poona, the Central Food and Technological Research Institute at Mysore, the Central Fuel Research Institute at Dhanbad, the Central Glass & Ceramics Research Institute at Calcutta, and the National Metallurgical Laboratory at Jamshedpur came into existence. Since then more and more national labora-

tories were established, one each in the years 1951, 1952, 1954, 1957, 1964 and 1966; two each were added in the years 1956, 1958, 1961 and 1965; and as many as five each were added in the years 1953 and 1959, thus bringing the total to 30 national laboratories located in scientific, industrial and technological fields.

Let us now see the vast organizational set-up of applied research in India. We begin with the scientific agencies, which take R & D as their main function. These are :

- (i) The Council of Scientific and Industrial Research until recently had 30 National Laboratories under its control employing a manpower of about 20,000. Out of these, the following laboratories are located in Uttar Pradesh : the Indian Institute of Petroleum, Dehradun, the Central Building Research Institute, Roorkee, the structural Engineering Research Centre, Roorkee, the Central Drug Research Institute, Lucknow, the Central Indian Medicinal Plants Organisation, Lucknow, the Industrial Toxicology Research Centre, Lucknow, and the National Botanical Research Institute, Lucknow.
- (ii) The Indian Council of Agricultural Research (ICAR) which has 29 Laboratories, and the manpower employed is over 17,000. Six of these laboratories are located in Uttar Pradesh.
- (iii) The Indian Council of Medical Research (ICMR) which has eight laboratories and the manpower employed is nearly 1,600.
- (iv) The Department of Atomic Energy (DAE) which was started under the leadership of Dr. H.J. Bhabha at Bombay for the purposes of harnessing atomic energy for peaceful purposes. It has more than seven laboratories and it employs over 14,000 persons.
- (v) The Defence Research and Development Organisation (DRDO). It has 31 laboratories or field research laboratories and employs over 18,000 persons. Six laboratories under this Organisation are located in Uttar Pradesh.
- (vi) Department of Space. It has its Rocket Launching facilities at the Shriharikota Range. At Trivandrum it has the Vikram Sarabhai Space Centre, the solid pro-

pellant Space Booster Plant and the Static Test and Evaluation Plant. The Space Applications Centre is located at Ahmedabad and the Indian Scientific Satellite Project is located at Bangalore. It employs over 8,000 persons.

In addition we have establishments under various Ministries and Departments, e.g., the India Meteorological Department, under the Ministry of Tourism and Civil Aviation, the Survey of India, the Zoological Survey of India, and the Botanical Survey of India under the Department of Science and Technology, and the Geological Survey of India, under the Department of Mines, and a host of other scientific and technological activities. R & D work is also undertaken by academic institutions and Universities. There are Scientific Departments under the State Governments which are also engaged in R & D work, for e.g., in Uttar Pradesh there are 11 such Centres including for example, the U.P. P.W.D. Research Institute, Lucknow, the Irrigation Research Institute, Roorkee, the Uttar Pradesh State Observatory, Nainital, etc. Public sector undertakings and private sector undertakings are also involved in R & D. Thus the R & D network in India is very expensive, but unlike in the more industrially advanced countries, most of the R & D work in India is pursued in government-supported laboratories. About 90% of the expenditure on science and technology come from the State and the Central Governments. This year this expenditure is expected to be around Rs. 500 crores.

Realizing that to promote rapid industrial growth in this country it was necessary to pursue applied and industrial research, Nehru's era saw to the creation of applied research institutes such as the CSIR, apart from the Universities and the industries. This was based on an earlier and similar set-up in UK. The Government subsequently became conscious of the need to promote industrial research within the industry and several financial incentives have been provided recently to encourage research within the industry. Since 1967, the Government has provided that capital expenditure incurred on research can be fully written off from profits. To bring industries closer to Universities and National Labora-

tories the Government has further allowed the writing off of 13.3% of the expenditure incurred in sponsoring research with universities and national laboratories. More than 500 industrial/research units have by now been registered with the Department of Science & Technology. This is a healthy trend. The investment for R & D from the private sector is now about 11% of the total R & D expenditure.

As I have said earlier, India has today the third largest number of trained scientists and engineers with a vast national infrastructure of R & D. About 3% of the total expenditure of the Central Government is devoted to R & D. This expenditure is about 0.6% of our GNP. It is interesting to compare this figure with the lay-out on R & D by some other countries. In 1974 USA spent about 2.3% of its GNP on R & D whereas UK about 2.0% of its GNP on R & D in 1972. Japan spent 2.5% of its GNP on R & D in 1975. The expenditure by USSR on R & D during 1973 was as high as 5% of its GNP.

The best method of conducting industrial research is to carry it out within the industry itself. There are encouraging signs and there is increasing involvement both in the public and the private sectors. It is in the interest of both, universities and national laboratories to encourage the establishment of good research units in the industries by suitable interaction and by supplying scientific and technical personnel. But this will also mean some adjustment within the universities and the national laboratories. The university researcher who has worked aloof from the industries should get acquainted with real industrial problems, their methods and practices. As active cooperation and sponsoring of problems by the industries in the universities is taking place, scientists from industrial undertakings do lecturing and guiding work in the universities and vice versa. National laboratories have also to reorient their projects and working. This can happen only if some scientists of R & D institutions work in the production units and vice versa for some period. This is actually happening in Western Europe where senior scientists in industries participate in teaching and training and many of them are recognized as professors. Besides, many graduates carry on research in industry for

obtaining higher University degrees. This leads to a valuable dialogue between industries and research institutions. On the other hand, in India heavy industries depend largely on foreign firms to supply the know-how which they wish to import every time. Thus the scientists and engineers employed in industries which depend on imported know-how, do not have much Design and Development work to do. They act only as maintenance engineers or are engaged in production, sales, management or similar scientifically non-innovative jobs.

It is high time that our leading scientists and engineers in the industry occupying responsible positions realised the importance of the Design and Development activity and took quick measures to organize it by utilizing the existing talent and creativity. Only if the industry takes Design and Development seriously shall we have materials and designs suited to Indian conditions. This would also generate employment for challenging jobs and is likely to reduce the 'brain drain'.



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